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CONTAMINATION CLEANUP**

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LITIGATION TECHNICAL SUPPORT AND SERVICES
ROCKY MOUNTAIN ARSENAL
SECTION 36 CONTAMINATION SURVEY
PHASE I SOURCE REPORTS INTRODUCTION
TASK NUMBER 1 (SECTION 36)
MAY 1986

ENVIRONMENTAL SCIENCE AND ENGINEERING

OFFICE OF PROGRAM MANAGER ROCKY MOUNTAIN ARSENAL
CONTAMINATION CLEANUP

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1.0 PROGRAM DESIGN

1.1 PHASE I OBJECTIVES

The Phase I soil boring program was designed to identify contamination present in unsaturated zone soils throughout the Rocky Mountain Arsenal (RMA). Soil borings in a square grid pattern and broad gas chromatography/mass spectrometry (GC/MS) scans were the primary techniques employed in this effort, which also included geophysical investigations and additional chemical analyses. The sampling and analytical programs are discussed in detail in Section 2.0 and 3.0, respectively. These methods were judged to be the most cost effective for defining the nature, level, and location of contamination over a large area containing multiple complex potential sources and uncontaminated areas. Results of Phase I investigations and plans for Phase II investigations are presented in the Source Reports which follow.

Several factors necessitated the use of a two-phase approach to soil contamination studies at RMA. The exact location and geometry of some previously reported potential source areas were questionable. The possibility existed that previously unreported sources were present. Where documentation of location was good, questions existed as to the level of contamination and compounds present. Thus, a "screening" procedure was designed to answer these questions and provide the necessary data so that a more focused and cost effective Phase II investigation could be designed and carried out.

1.2 PHASE II OBJECTIVES

In designing the Phase II programs, the main objective was to provide a sampling and analytical scheme capable of defining the vertical and horizontal extent of contamination at specific sources. This will require quantitative analyses of appropriate compounds within and beyond the contaminated areas. Geostatistical techniques can then be used to delineate volumes which are contaminated above a specified level. The ultimate goal of this effort, and the entire Remedial Investigation (RI) process, is to define what materials require remediation and characterize the level and nature of contamination in those materials.

The Phase II programs presented in the various source reports were designed to obtain this information by employing a modified grid sampling strategy and quantitative analysis of the chemicals of interest at each source. Chemical methods will include, as appropriate, gas chromatography (GC), Atomic Absorption (AA), and Inductively Coupled Argon Plasma (ICAP). In each case, the sampling locations and analytical scheme were based on source geometry and chemicals identified in Phase I.

1.3 RELATIONSHIP TO OTHER TASKS

The soil boring and sampling program described herein is only a small part of the overall RI effort currently ongoing at RMA. Studies of contamination in ground water, surface water, air, buildings, and biota are being conducted under other task orders. An endangerment assessment and studies to establish action levels for cleanup are also underway. Descriptions of task objectives and technical plans for the various tasks initiated are available through Program Manager's Office-Rocky Mountain Arsenal (PMO-RMA). Ultimately, data from all these efforts will be integrated to form a comprehensive examination of the sources of soil contamination, migration of contaminants, and impacts of contamination on RMA and in surrounding areas.

The efforts described in these Phase I reports and the associated Phase II plans are designed to identify the nature and extent of contamination in the unsaturated soil zone above the water table within RMA. Questions related to potential ground water impacts and biota effects can only be answered by consideration of pertinent studies from other tasks.

1.4 USE OF HISTORICAL INFORMATION

A considerable body of historical information on contamination at RMA was available prior to the design of Phase I soil sampling programs. Additional significant information was obtained during Phase I investigations. Historical information was obtained in the form of previous investigative studies, aerial photographs, and depositions of key personnel. The specific nature and use of such information is discussed below. In all cases, this information was employed as a tool in designing cost-effective studies. Sufficient sampling was conducted

to support or refute source designations and/or boundaries. These were revised as appropriate when additional information became available.

RMA personnel have performed numerous investigative activities over the past 20 years to identify locations where activities may have resulted in soil contamination. The results of these investigations are summarized in many reports and data are tabulated in a computerized data base. One of the more comprehensive reports summarizing the locations and estimated extent of soil contamination is the RMA Decontamination Report (RMACCPMT, 1984). In the process of investigating soils at RMA, comprehensive maps were prepared that summarize the locations, extent, and probable use of over 150 potential contaminant sources. This information was used as the basis for the initial source designations, source boundaries, and uncontaminated areas boundaries. These were later revised as appropriate using additional information.

Historical aerial photographs from dates as early as 1948 were located and reviewed to help delineate which sections of RMA exhibited surficial disturbances that may have resulted from the disposal of hazardous materials. These aerial photographs are available at intervals not greater than five years from 1948 to present. Photographic examination reveals that ground scars remain visible for more than five years. Ground scars identified on aerial photographs were investigated as potential contaminant sources. If disposal activity records were either not available or suggestive of contaminant disposal, the ground scars were subjected to a Phase I soil investigation. The aerial photographs were also used to confirm the location and configuration of known sources and to confirm areas historically free of disturbances.

The third main source of information of past activities was depositions taken from key RMA and Shell personnel, both those currently employed at RMA and those that work elsewhere or have retired. These interviews aided in determining the use of sites identified from aerial photographs and RMA records. Interviews in some cases confirmed the disposal practices that occurred at specific sites while in other cases these interviews provided disposal history for sites where no documentation was

available. Valuable information was obtained from RMA and Shell personnel concerning identification of chemical spill sites in the South Plants area.

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2.0 SAMPLING STRATEGY

2.1 PHASE I

2.1.1 UNCONTAMINATED AREAS

Large portions of RMA have never been utilized for the manufacture, handling or disposal of hazardous materials. This has been documented by several methods including interpretation of aerial photographs, examination of RMA records, and interviews with RMA and Shell personnel. The results of these activities show that sections located along the RMA perimeter contain few potential contamination sources and that most interior sections of RMA have extensive areas where no potential sources have been identified. These portions of RMA were designated as uncontaminated for the current remedial investigation.

To confirm that these uncontaminated areas are free of significant contamination they were investigated under RMA Phase I programs. If contaminants were detected, the area in question was either included within the boundary of an existing source or designated as an additional source and subject to an appropriate Phase I or Phase II investigation.

Spacing of borings in uncontaminated areas was not intended to identify small contaminant sources but to confirm or refute the historical information showing these areas were not subjected to disposal activities. Borehole spacings for each section (1 square mile) were selected at 1,000 ft, 750 ft, or 500 ft based on best professional judgment and cost effectiveness. Spacing of 1,000 ft was used in uncontaminated areas of sections that contain very few potential contaminant sources of limited aerial extent. Borehole spacing of 750 ft was selected for sections which contain moderate proportions or number of potential contaminant sources. Borehole spacing of 500 ft were used in uncontaminated portions of sections that have a high proportion of contaminant sources such as Section 36.

All boreholes in uncontaminated areas were drilled to 5 ft and samples were collected from depths of 0 to 1 and 4 to 5 ft. All RMA disposal activities involved disturbance of soils shallower than 10 ft. A single

sample of near surface soil (0 to 1 ft) would provide sufficient confirmation for contaminants such as the organochlorine pesticides or trace metals in the upper foot of soil. An additional sample was collected in each borehole from a depth of 4 to 5 ft to ensure that more mobile contaminants leached from near surface soils were detected. An additional reason for collecting 4 to 5 ft samples is that trench disposal may have resulted in the presence of contaminants at depths of 2 to 7 ft but the trench could have been covered with clean overburden material. It should be emphasized that no such activities were observed in aerial photographs or RMA records for uncontaminated areas. If such activities were observed, the uncontaminated area designation would be changed and the areas would be investigated as a potential source.

The two samples from each borehole in uncontaminated areas were composited to provide the most cost effective approach to confirming the lack of contamination in the large portions of RMA where no disposal activities had previously occurred. Samples were composited only from within a single borehole. Any detection of contaminants could thus be traced to a specific location and a Phase I source program initiated. As only two samples were composited, minimal dilution of potential contaminants would have occurred. If contaminants were present in one horizon and not in the other a worst case situation may develop. Under such conditions, assuming one sample is completely free of contamination, a maximum contaminant dilution of 50 percent would result. For example, the 0 to 1 ft sample may contain 40 mg/kg of Dieldrin and the 4 to 5 ft sample none. The composite sample would then contain a concentration near 20 mg/kg. Therefore, sample compositing procedure does not induce significant sample dilution. It does artificially increase the effective detection limit by a factor of two. If the analytical detection limit for Dieldrin is 0.3 mg/kg the case described above would have an effective detection limits of 0.6 mg/kg for each sample.

2.1.2 SOURCE AREAS

An empirical curve was developed for estimating the total number of Phase I and Phase II samples that could not be logistically and cost

effectively obtained in the soils investigations. This curve was primarily used to obtain the number of Phase I boreholes at any source. A secondary purpose of this curve was to obtain an estimated number of Phase II boreholes for budgetary and labor estimates. The Phase II program for each source is designed based on Phase I data and in general did not strictly adhere to estimates from the empirical curve.

The empirical curve was developed based on the best professional judgment of two teams of consultants. An estimate of the level of effort required for the soils investigation at over 40 individual contaminant sources was assembled and compiled. These estimates were based on the method of contaminant disposal and the estimated area of each source. Soil investigation programs for these 40 contaminant sources were combined into the empirical curve. Phase I and Phase II programs for each source were modified to conform to the empirical curve.

To provide uniformity and consistency in the sampling of subsurface soils and allow interpretation and contouring of contaminant concentration data, regular sampling intervals were established. In cores where visual evidence of contamination was observed or high concentrations of volatile organics (OVA or HNU) were detected in soil intervals other than the regular sampling intervals, additional samples were added to the sample train at the discretion of the site geologist.

For the Phase I investigation no samples were scheduled beneath the water table. This strategy was established to prevent possible cross contamination of ground water by contaminants in overlying soils. Soils beneath the water table may show degraded soil quality as a result of ground water transport that is not representative of overlying soil column contributions. This evaluation of contamination in saturated soils is not an objective of the soil investigations (Tasks 1, 6, 14) but will be addressed in ground water related tasks (4, 25).

The exception to the rule of not sampling beneath the water table in Phase I investigations was for soil borings in trench disposal areas. Fluctuations in ground water table elevation may have resulted in higher

water tables at locations where previous trench disposal occurred. In these cases, soil sampling proceeded past the water table to the maximum depth of trenching or disposal activities as determined by the site geologist based on visual inspections of the soil core.

2.2 PHASE II

The grid patterns and boring densities for Phase II investigations have been designed based on Phase I results. The number and placement of borings and samples for Phase II presented in the source reports were selected specifically to augment Phase I data as necessary to meet Phase II objectives. The depth and distribution of sampling in Phase II investigations will depend on the assessment of Phase I data. In some instances where contamination is present in significant concentrations immediately above the water table or the water table appears to have risen since contaminant disposal, soil samples will be collected beneath the water table contact.

In several instances, source designations and/or boundaries for Phase II were changed. Where Phase I data indicate previously designated boundaries are incorrect, the boundaries were altered to properly reflect the area impacted by a given source. This includes dropping and/or combining some sources for Phase II investigations, where this is justified by Phase I data. The intent of this process is to properly designate areas which exhibit a correlation in the nature of contamination, and are related to a particular disposal practice or episode. It would be unreasonable to maintain boundaries based on historical information considering recently acquired scientific evidence to the contrary.

3.0 ANALYTICAL STRATEGY

3.1 PHASE I

Detailed descriptions of analytical methods for Phase I chemical analyses have been distributed to all interested parties. The analytical parameters and detection limits of these methods are presented in Table 3.1-1. Modified U.S. Environmental Protection Agency (EPA) gas chromatography/mass spectrometry (GC/MS) Methods 624 and 625 were used for analysis of organic compounds. An ICP metals screen was used for base metals (Pb, Cd, Zn, Cu, Cr). Separate methods were used for As, Hg, and DBCP. The separate DBCP method was dropped later in the soils program, after it was determined that DBCP was amenable to inclusion in the GC/MS methods. In general, all five methods were used for Phase I samples. The exception to this was the VOA analyses. In sources where the history indicated no disposal of volatiles, only 10 percent of the samples selected from deep intervals were subjected to VOA analysis. In addition, VOA's were not run on the 0 to 1 ft interval samples, on the assumption that no VOA's would be found. Also, VOA's were not run in uncontaminated areas because the compositing procedure rendered the analysis inaccurate.

In areas where chemical agents were expected, RMA laboratory performed screening for mustard and CB agents. The procedure employed and areas sampled for these constituents are described in the source reports.

3.2 PHASE II

Detailed descriptions of chemical methods for Phase II organic analyses will be documented under a separate cover. In general, they consist of quantitative GC methods (EPA 601, 602, 608, etc.) which cover the same suite of analytes studied in Phase I as well as any additional analytes recommended for inclusion. Methods for metals, As, Hg, and DBCP will remain the same. The target detection limit for organic analyses established prior to certification was 0.05 ppm. Certified detection limits will be included in the detailed methods.

Table 3.1-1. Phase I Analytical Parameters and Reporting Limits

Analytes	Reporting Limits ^{1,2} (µg/g)			
	ESE	MRI	UBTL	CAL
Volatile Organics				
Chloroform (CHCl ₃)	0.3	0.7	0.3	0.3
1,1-Dichloroethane (1,1-DCA)	0.3	0.5	2	0.9
Methylene chloride (CH ₂ Cl ₂)	0.3	—	2	0.7
1,2-Dichloroethane (1,2-DCA)	0.3	0.4	0.6	0.3
1,1,1-Trichloroethane (1,1,1-TCA)	0.3	0.5	0.4	0.3
1,1,2-Trichloroethane (1,1,2-TCA)	0.3	0.6	0.4	0.3
Carbon Tetrachloride (CCl ₄)	0.3	0.4	0.3	0.3
Tetrachloroethylene (PCE)	0.3	0.5	0.3	0.3
Trichloroethylene (TCE)	0.3	0.6	0.5	0.3
Trans-1,2-Dichloroethylene (DCE)	0.3	0.8	2	0.3
Benzene	0.3	1	0.3	0.3
Toluene	0.3	0.3	0.3	0.3
Ethylbenzene	0.3	0.4	0.4	0.3
Chlorobenzene	0.3	0.3	1	0.3
MIBK	0.5	0.4	0.7	0.3
Dimethyldisulfide	0.3	4	20	0.8
Bicycloheptadiene (BCHD)	0.3	0.8	0.4	0.3
Dibromochloropropane (DBCP)	0.3	0.9	2	4
m-Xylene	0.3	0.3	0.8	0.7
o- and/or p-Xylene	0.5	0.5	5	3
Semi-Volatile Organics				
Aldrin	0.9	0.5	0.3	0.3
Endrin	0.7	4	0.5	0.3
Dieldrin	0.3	0.6	0.4	0.3
Isodrin	0.3	0.6	0.3	0.3
p,p'-DDT	0.4	2	0.5	0.6
p,p'-DDE	0.3	0.5	0.6	0.3
Hexachlorocyclopentadiene (HCCPD)	1	1	0.6	0.3
1,4-Oxathiane	0.3	0.5	0.3	6
Dithiane	0.3	2	0.4	7
Malathion	0.6	2	0.7	0.3
Parathion	0.7	2	0.9	0.4
Chlordane	1	6	2	0.6
Supona	0.5	0.9	0.6	0.3
Diisopropylmethylphosphonate (DIMP)	0.5	3	1	0.3
Dimethylmethylphosphonate (DMMP)	2	3	—	—
Atrazine	0.7	0.5	0.3	0.3

Table 3.1-1. Phase I Analytical Parameters and Reporting Limits

Analytes	Reporting Limits ^{1,2} (µg/g)			
	ESE	MRI	UBTL	CAL
Semi-Volatile Organics				
Dicyclopentadiene (DCPD)	0.3	6	1	0.4
Vapona	0.3	0.3	3	0.3
Chlorophenyl methyl sulfide (PCPMS)	0.3	0.3	0.9	4
Chlorophenyl methyl sulfoxide (PCPMSO ₂)	0.3	0.4	0.3	0.6
Chlorophenyl methyl sulfone (PCPMSO)	0.4	1	0.3	7
Dibromochloropropane (DBCP)	0.005	0.005	0.005	0.014
ICP Metal Screen				
Chromium	7.2	7.4	6.5	5.2
Zinc	6	28	8.7	9.5
Cadmium	0.9	0.5	0.7	0.7
Copper	4.8	4.9	4.7	4.9
Lead	17	16	8.4	13
Arsenic	4.7	5.2	3.6	5.0
Mercury	0.05	0.07	0.05	0.06

- 1 Detection levels vary among the four laboratories currently conducting chemical analyses.
- 2 Agent screening conducted only at Rocky Mountain Arsenal Laboratory. Report Limits (µg/g) are: GB, 0.08 and HD, 2.1.

Source: Task 1 Technical Plan, ESE, 1984.

During the Phase II investigation, only selected methods will be run on each sample. This will be determined based on Phase I data. Methods will be chosen as appropriate to quantify the extent of contamination for analytes encountered in Phase I. Analytes scheduled for each sample are presented in the individual source reports.

In areas where Phase I samples required dilution to facilitate analysis, the possibility exists that this dilution may have "masked" the presence of some compounds by raising the effective detection level. These situations are being examined on an individual basis with consideration given to data from surrounding areas. An expanded suite of Phase II analyses and/or additional GC/MS analyses will be used to insure that significant analytes are detected. This same philosophy is applied where the presence of agents precluded contractor analysis of Phase I samples.

The Phase II investigation also contains provisions for GC/MS confirmation of GC findings to precisely identify the compounds being reported. Approximately 10 percent of the positive GC findings will be confirmed on GC/MS. These will be selected based on source, sample location, and GC results, to make sure confirmation is available in all sources for significant analytes.

Various parties have requested inclusion of additional chemical analysis methods in the Phase II program. These include various breakdown products of chemical agents, and organic arsenic compounds. This question is under consideration by PMO-RMA.

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4.0 INDICATOR LEVELS

To determine the relative significance of soil quality data from suspected source areas, an evaluation of background soil quality was performed. The objective of this evaluation was to establish baseline soil quality for RMA. The assessment of natural or background ranges of concentrations for potential RMA contaminants, primarily metals, is essential to the evaluation of Phase I soil data. With baseline conditions established, the impact on soil quality that has resulted from disposal and manufacturing practices can be assessed.

The first method used in this evaluation was a literature search to determine natural ranges of potential contaminants in soils, specifically those of the western United States. The second method utilized to establish baseline conditions was the chemical analysis of a bulk soil sample that was collected and homogenized to serve as a soils matrix for the project laboratories. The final method was the tabulation and evaluation of soil quality data from uncontaminated areas of RMA.

At the time of this evaluation, soil quality data was available for 24 of the 27 sections at RMA. This establishment of baseline soil conditions was primarily directed at natural variations for metals including arsenic, cadmium, chromium, copper, mercury, lead, and zinc.

4.1 LITERATURE REVIEW

A literature review was performed to determine natural ranges and average values for metals concentrations in uncontaminated soil. References examined included Kabata-Pendias and Pendias, 1984; Shacklette and Boerngen, 1984; and Wedepohl, 1970. Values obtained from the first two references are presented in Table 4.1-1. Mean concentrations are reported in addition to concentration ranges. Many of these ranges for metal concentrations show significant variability. Due to the variety of soil series at RMA, some variability in trace metal concentrations is to be expected, although variability is expected to be significantly less than reported for all soils from the western United States.

Table 4.1-1. Representative Concentrations of Inorganic Constituents in Uncontaminated Soils (units in $\mu\text{g/g}$ or ppm)

	<u>Various USA Soils¹</u>		<u>Western USA Soils and Surficial Materials²</u>	
	Mean	Range	Geometric Mean	Range
Cd	-	0.41-0.57	-	-
Cr	-	-	41	3-2000
Cu	26	3-300	21	2-300
Pb	26	<10-70	17	<10-700
Zn	74	13-300	55	10-2100
As	7.0	<1.0-93	5.5	<0.10-97
Hg	0.17	0.02-1.50	0.46	<0.01-4.6

1 Kabata-Pendias and Pendias (1984).

2 Shacklette and Boerngen (1984).

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Two metals of primary concern at RMA are mercury and arsenic. Wedepohl (1970) reports that 30 percent of all soils typically contain less than 5 ppm As, 50 percent contain 5 to 10 ppm, and approximately 20 percent contain As concentrations in excess of 10 ppm. Average soils contain As at concentrations between 5 and 10 ppm. Wedepohl (1970) reports that average Hg concentrations in soils may range from 150 to 400 ppb with several documented studies reporting averages in the 400 ppb range. Sandstones contain lower concentrations of Hg (30 to 100 ppb). Cadmium values reported by Wedepohl (1970) for sedimentary rocks average 0.8 ppm for shales and claystones with a range of 0.3 to 11 ppm.

Table 4.1-2 contains ranges of metal concentrations in both soils and shales in $\mu\text{g/g}$ or mg/kg . Upon comparison of these ranges it is apparent that concentrations of these four metals are higher in shale than in soils. This is largely a result of mineralogic variability in different sediment types and the subsequent leaching of metals from rock during soil formation.

4.2 BULK SOIL

Early in the Phase I program a bulk soil sample was collected just off the northeast corner of RMA in an area exhibiting Ascalon-Vona sandy loam and Ascalon sandy loam soils associations. This bulk sample was dried and homogenized and then served as the substrate for laboratory spikes and as the blank used in laboratory QC procedures. The resulting multiple determinations of arsenic, cadmium, lead, and mercury are below the analytical detection limits of 4.7, 0.9, 17, and 0.05 ppm, respectively. In general, organic contaminants have been undetectable in these soil samples, with the exception of occasional detectable low concentrations of laboratory solvents. These values represent repeated analysis of a single, homogenized sample. They do not represent variability expected in multiple samples from various RMA locations.

Chemical analysis of this standard soil yielded detectable concentration of chromium, copper, and zinc. The results of these repeated analyses are tabulated in Table 4.2-1.

Table 4.1-2. Comparison of Median Background Trace Metal Concentrations in Soils and Shales from Selected Regions of the United States.

	<u>Range of Median Concentrations (ppm)</u>	
	Soil	Shale
Cu	8.7-39	13-130
Hg	30-160	45-340
Pb	2.6-27	11-24
Zn	25-68	55-82

Source: Connor, J.J., and Shacklette, H.T. 1975.

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Table 4.2-1. Bulk Soil Sample Composition

Element	Average Concentration Bulk Soil (ppm)
Cd	<0.9
Cr	14
Cu	16
Pb	<17
Zn	40
As	<4.7
Hg	<0.05

Source: ESE, 1986.

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4.3 SOIL QUALITY IN UNCONTAMINATED AREAS

The contamination assessment for soils at RMA includes the sampling and analysis of near surface soils from portions of RMA that are considered uncontaminated. The primary objective of this activity is to ensure, with a reasonable degree of certainty, that these areas are in fact uncontaminated. However, these data can also be used in conjunction with literature derived values to estimate background soil composition.

Sampling and analysis of soils from 24 of the 27 sections has been completed and these data are available for evaluation. All soil samples from these uncontaminated borings were collected in the field as 0 to 1 ft, and 4 to 5 ft core sections. These two sampling intervals were composited in the laboratory prior to analysis. Therefore, the results yield an integrated concentration for the upper 5 ft of soil. If extreme distributions of metals exist within the 0 to 5 ft horizon, the values obtained from these studies may not agree with values obtained for specific soil depths.

The results of these studies of uncontaminated areas are presented in Table 4.3-1 through 4.3-7. Concentration ranges for each metal are reported for each section as well as mean and median values. When calculating mean values, concentrations measured below detection limits were excluded.

In order to evaluate the variability of metal concentrations between soil series, a detailed assessment of soil quality data from uncontaminated portions of Section 36 was performed. Samples were grouped according to soil series as determined from the Adams County Soil Survey (Sampson and Barber, 1974). The range of concentrations encountered for each soil type are presented in Table 4.3-8. In general, the finer textured soils have higher metals concentrations. Samples containing organic contaminants and isolated samples exhibiting elevated concentrations of inorganic analytes were omitted from this evaluation, as indicated. Cadmium concentrations were below the analytical detection limit in all Section 36 uncontaminated area samples. The range of concentrations in each soil type appear similar for each target element, although the numbers of valid samples in each category are generally not sufficient

Table 4.3-1.

COMPOUND: ARSENIC
 ESE D.L. 4.7 ug/g
 MRI D.L. 5.2 ug/g
 URTL D.L. 3.6 ug/g
 CAL D.L. 5.0 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	1	2.7	--	--	--
2	68	0	--	--	--	--
5	27	5	2.5-3.3	2.9	2.9	0.29
6	43	7	2.5-3.5	3.0	2.9	0.39
7	27	0	--	--	--	--
8	27	0	--	--	--	--
9	24	0	--	--	--	--
11	27	0	--	--	--	--
12	26	0	--	--	--	--
19	24	0	--	--	--	--
20	25	0	--	--	--	--
22	12	0	--	--	--	--
23	25	0	--	--	--	--
24	25	0	--	--	--	--
25	49	8	5.8-50	7.6	17	19
26	36	6	5.2-9.3	5.6	6.5	1.7
27	25	1	12	--	--	--
28	9	0	--	--	--	--
29	24	10	5.9-7.6	6.6	6.6	0.49
30	36	2	5.8-21	--	--	--
31	33	7	3.0-3.9	3.3	3.4	0.37
32	27	6	3.2-4.9	4.1	3.2	0.66
34	25	0	--	--	--	--
35	44	3	5.4-12	5.4	7.6	3.8
36	58	24	4.7-18	5.9	6.6	2.95
TOTAL	798	80	2.5-50	5.6	6.8	7.2

% DETECTABLE= 10%

RECOMMENDED INDICATOR LIMITS
 ESE=10-15
 SHELL=4.7-10
 CDH=4.7

Table 4.3-2.

COMPOUND: CADMIUM
 ESE D.L. 0.9 ug/g
 MRI D.L. 0.5 ug/g
 UBTL D.L. 0.7 ug/g
 CAL D.L. 0.7 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	0	--	--	--	--
2	68	1	0.99	--	--	--
5	27	0	--	--	--	--
6	43	0	--	--	--	--
7	27	0	--	--	--	--
8	27	0	--	--	--	--
9	24	0	--	--	--	--
11	27	0	--	--	--	--
12	26	0	--	--	--	--
19	24	0	--	--	--	--
20	25	0	--	--	--	--
22	12	1	2.7	--	--	--
23	25	5	1.0-4.5	2.8	2.7	1.4
24	25	1	0.77	--	--	--
25	49	2	1.0-1.1	--	--	--
26	36	1	6.5	--	--	--
27	25	0	--	--	--	--
28	9	0	--	--	--	--
29	24	0	--	--	--	--
30	36	0	--	--	--	--
31	33	*	*	*	*	*
32	27	0	--	--	--	--
34	25	0	--	--	--	--
35	44	1	7.8	--	--	--
36	58	0	--	--	--	--
TOTAL	798	12	0.66-7.8	2.1	2.7	2.3

% DETECTABLE= 2%

RECOMMENDED INDICATOR LEVELS

ESE=2-5

SHELL=0.9

CDH=0.5

ICP METALS NOT ON THE DATABASE YET

Table 4.3-3.

COMPOUND: CHROMIUM
 ESE D.L. 7.2 ug/g
 MRI D.L. 7.4 ug/g
 UBTL D.L. 6.5 ug/g
 CAL D.L. 5.2 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	33	6.4-24	9.7	11	3.6
2	68	29	8.2-20	10	11	2.5
5	27	20	9.2-28	12	14	4.2
6	43	32	6.9-22	13	13	4.7
7	27	22	9.7-24	14	15	3.5
8	27	23	8.1-16	10	11	2.1
9	24	23	8.3-18	12	12	2.7
11	27	15	8.1-15	11	12	2.6
12	26	21	8.1-17	12	12	2.4
19	24	17	10-23	14	14	3.8
20	25	24	9.7-23	17	16	3.5
22	12	12	10-19	13	14	2.2
23	25	23	12-21	16	16	2.8
24	25	25	9-21	17	17	3.2
25	49	46	11-21	16	16	2.5
26	36	32	9-23	12	14	4.0
27	25	18	8.6-15	11	11	1.8
28	9	5	11-15	13	13	1.6
29	24	24	12-27	17	17	3
30	36	31	10-30	15	15	4
31	33	*	*	*	*	*
32	27	16	9.6-55	21	22	9.8
34	25	10	9.0-16	12	12	2.2
35	44	30	7-17	11	11	2.7
36	58	49	7-17	10	11	2.4
TOTAL	798	580	6.4-55	13	14	4.4

% DETECTABLE= 73%

RECOMMENDED INDICATOR LEVELS

ESE=30-50
 SHELL=15-25
 CDH=15-17

* ICP METALS NOT ON THE DATABASE YET

Table 4.3-4.

COMPOUND: COPPER

ESE D.L. 4.8 ug/g

MRI D.L. 4.9 ug/g

UBTL D.L. 4.7 ug/g

CAL D.L. 4.9 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	28	5.8-17	8.2	9.2	2.5
2	68	26	5.8-24	7.2	8.6	3.7
5	27	17	6.5-19	8.7	9.7	3.0
6	43	34	6.0-69	9.1	12	11
7	27	17	6.3-17	11	11	3.6
8	27	16	6.0-13	8.1	8.8	2.2
9	24	22	5.9-17	8.7	9.6	3.3
11	27	25	6.2-12	7.7	8.1	1.6
12	26	11	6.1-9.0	7.7	7.5	1.1
19	24	22	6.3-28	14	14	5.0
20	25	25	6.5-20	15	15	3.1
22	12	12	18-28	21	21	2.9
23	25	25	5-20	11	12	4.0
24	25	25	11-22	16	16	2.9
25	49	49	11-53	16	16	5.9
26	36	36	6-21	10	12	4.2
27	25	25	6.2-32	16	17	5.1
28	9	8	9-24	16	15	4.7
29	24	24	9.0-19	14	14	2.3
30	36	31	7.3-46	12	14	7.3
31	33	*	*	*	*	*
32	27	15	9.9-40	14	15	7.2
34	25	25	9-20	13	14	3.1
35	44	44	5-25	7.0	8.9	4.4
36	58	58	5-18	8.5	9.0	2.7
TOTAL	798	620	5-46	11	12	5.7

% DETECTABLE= 78%

RECOMMENDED INDICATOR LEVELS

ESE=20-50

SHELL=15-25

CDH=15-20

* ICP METALS NOT ON THE DATABASE YET

Table 4.3-5.

COMPOUND: MERCURY

ESE D.L. 0.05 ug/g
 MRI D.L. 0.07 ug/g
 UBTL D.L. 0.05 ug/g
 CAL D.L. 0.06 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	2	0.06-0.19	--	--	--
2	68	1	0.06	--	--	--
5	27	0	--	--	--	--
6	43	0	--	--	--	--
7	27	0	--	--	--	--
8	27	0	--	--	--	--
9	24	0	--	--	--	--
11	27	0	--	--	--	--
12	26	0	--	--	--	--
19	24	0	--	--	--	--
20	25	0	--	--	--	--
22	12	1	0.091	--	--	--
23	25	0	--	--	--	--
24	25	0	--	--	--	--
25	49	2	0.076-0.45	--	--	--
26	36	1	0.11	--	--	--
27	25	0	--	--	--	--
28	9	0	--	--	--	--
29	24	0	--	--	--	--
30	36	0	--	--	--	--
31	33	2	0.087-0.16	--	--	--
32	27	0	--	--	--	--
34	25	0	--	--	--	--
35	44	0	--	--	--	--
36	58	18	0.05-1.2	0.08	0.22	0.29
TOTAL	798	27	0.05-1.2	0.087	0.20	0.26

% DETECTABLE= 3%

RECOMMENDED INDICATOR LEVELS

ESE=0.1-0.2
 SHELL=0.05-0.1
 CDH=0.5

Table 4.3-6.

COMPOUND: LEAD
 ESE D.L. 17 ug/g
 MRI D.L. 16 ug/g
 UBTL D.L. 9.4 ug/g
 CAL D.L. 12.7 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	29	11-44	15	18	6.7
2	68	28	11-23	15	15	3.0
5	27	5	12-16	12	13	1.7
6	43	6	12-17	14	14	2.1
7	27	10	11-16	13	13	1.8
8	27	7	11-17	15	14	2.2
9	24	9	10-16	12	12	1.8
11	27	10	11-14	12	12	0.97
12	26	7	13-120	18	41	40
19	24	1	29	--	--	--
20	25	3	20-25	21	22	2.6
22	12	3	19-27	21	22	3.8
23	25	5	22-27	22	23	2.1
24	25	4	21-24	23	23	1.4
25	49	3	22-37	27	29	7.6
26	36	10	18-25	20	21	2.5
27	25	0	--	--	--	--
28	9	0	--	--	--	--
29	24	0	--	--	--	--
30	36	0	--	--	--	--
31	33	*	*	*	*	*
32	27	7	13-20	14	15	2.7
34	25	2	22-24	--	--	--
35	44	10	17-41	20	21	7.2
36	58	31	17-30	20	22	3.3
TOTAL	798	190	10-120	17	19	10

% DETECTABLE= 24%

RECOMMENDED INDICATOR LEVELS
 ESE=30-75
 SHELL=20-30
 CDH=20

* ICP METALS NOT ON THE DATABASE YET

Table 4.3-7.

COMPOUND: ZINC
 ESE D.L. 16 ug/g
 MRI D.L. 28 ug/g
 UBTL D.L. 8.7 ug/g
 CAL D.L. 9.5 ug/g

SECTION	# SAMPLES	# > D.L.	RANGE	MEDIAN	MEAN	STD. DEVIATION
1	52	52	12-85	32	35	16
2	68	67	14-70	30	32	11
5	27	22	16-63	39	39	12
6	43	39	15-76	36	39	16
7	27	24	11-66	40	40	13
8	27	26	17-51	34	34	8.1
9	24	24	26-62	38	39	10
11	27	27	17-46	27	29	7.5
12	26	25	21-48	32	33	7.1
19	24	17	36-71	46	48	9.7
20	25	23	35-72	55	53	9.1
22	12	12	33-58	44	44	6.2
23	25	24	35-66	56	55	9.0
24	25	22	37-92	48	52	12
25	49	49	34-100	53	54	11
26	36	26	28-65	41	43	9.5
27	25	16	33-66	38	41	8.8
28	9	5	41-53	44	45	4.7
29	24	24	40-73	55	56	7.6
30	36	31	38-81	51	53	11
31	33	*	*	*	*	*
32	27	16	31-180	70	75	31
34	25	10	33-57	43	44	7.5
35	44	43	22-52	30	32	8.1
36	58	58	28-280	40	40	32
TOTAL	798	682	11-280	41	42	18

% DETECTABLE= 85%

RECOMMENDED INDICATOR LEVELS
 ESE= 80-100
 SHELL= 60-80
 CDH= 50

ICP METALS NOT ON THE DATA BASE YET

Table 4.3-8. Evaluation of Metals Concentration by Soil Series in Section 36
Uncontaminated Borings (Units in $\mu\text{g/g}$ or ppm)

Parameter	Soil Description	Concentration		Number of Determinations Above Detection Limit	Comments
		Minimum	Maximum		
Cr	PlB	<7.0	17	18	
	AvC	<7.0	15	17	
	AsB	<7.0	12	7	
	TuD	8.0	13	4	
	Gr	<7.0	<7.0	0	
Cu	PlB	7.0	13	18	
	AvC	5.0	12	20	
	AsB	5.0	16	11	
	TuD	5.0	7.0	4	
	Gr	6.0	18	2	
Pb	PlB	<17	27	11	
	AvC	<17	25	10	
	AsB	<17	26	6	
	TuD	<17	19	1	
	Gr	<17	19	1	
Zn	PlB	31	54	18	
	AvC	28	54	20	
	AsB	28	48	11	275 @ 3041
	TuD	28	45	4	
	Gr	28	53	2	
As	PlB	<4.7	6.8	12	
	AvC	<4.7	6.1	5	
	AsB	<4.7	6.3	5	10 @ 3041
	TuD	<4.7	<4.7	0	
	Gr	<4.7	<4.7	0	
Hg	PlB	<0.05	0.08	6	0.18 @ 3001
	AvC	<0.05	0.10	3	
	AsB	<0.05	0.44	6	1.15 @ 3012
	TuD	<0.05	<0.05	0	
	Gr	<0.05	<0.05	0	

PlB - Platner loam

AvC - Ascalon-Vona sandy loam

AsB - Ascalon sandy loam

TuD - Truckton sandy loam

Gr - Gravelly land-Shale outcrop

Samples exhibiting organic contaminants (3042, 3049, and 3053) have been omitted.
Isolated samples exhibiting elevated concentrations have been noted.

Source: ESE, 1985.

for rigorous statistical evaluation. Section 36 maximum uncontaminated area soil concentrations also appear similar to the mean United States soils concentrations reported in the literature for the six inorganic target compounds reviewed.

This evaluation of environmental background conditions for metals is valid only for soils, not for weathered or consolidated bedrock materials. Shales, such as those commonly encountered at the alluvium bedrock contact in Section 36, are often enriched in trace elements. Naturally occurring trace elements are preferentially adsorbed to clay minerals during the formation of shales, leading to relative trace element enrichment in these sediments. This effect is illustrated in Table 4.1-2, where median concentrations of four metals in both soils and shales from groups of samples collected throughout the United States are tabulated. Ranges of median concentrations are consistently higher in shales as compared to soils.

This hypothesis is verified by soil quality data from boreholes that encounter the Denver Formation. For example, Source 36-12, originally thought to be a landfill location, was found to be uncontaminated after evaluation of Phase I data. Boreholes in this source area encountered the Denver Formation at shallow depth and due to the consolidated nature of this bedrock, could not penetrate deeper than 18 ft. Ranges of some metals concentrations measured in these less weathered samples were significantly higher than concentrations measured in the shallow boreholes constructed in uncontaminated areas. Concentrations of copper, lead, and zinc were consistent between boreholes with depth and range from 18 to 47 ppm, 17 to 60 ppm, and 30 to 101 ppm, respectively. Therefore, elevated concentrations encountered in RMA studies are probably not a result of disposal activities, but may fall within the range of natural variability for different geologic media. Similar trends of increased and consistent metals concentrations with depth have been observed in several other portions of RMA. Elevated metals concentrations in areas of bedrock highs will be evaluated with respect to the lithology encountered during drilling.

4.4 SELECTION OF INDICATOR LEVELS

The term indicator level as used in this report refers to a concentration range for each potential contaminant above which that contaminant approaches levels beyond natural variability. These indicator ranges are not to be considered action levels for remediation, as they are not based on toxicity. The decision to include a specific contaminant in a Phase II program was not made solely on the exceedance of indicator levels but also upon consideration of site conditions, site history, hydrology, as well as variability and frequency of detectable concentrations. Values below the established range were not recommended for Phase II examination. Values within the range were assessed on a case by case basis. Values above the ranges shown were generally referred to Phase II unless some explanation such as geologic strata was found.

For organic compounds, these indicator levels are the detection limit for a given method. The detection limit was selected for organic compounds because they are not naturally occurring compounds and therefore any detectable concentrations are the result either of disposal practices, agricultural practices (e.g., pest control), or dispersion from source areas (e.g., wind blown). A list of the analytical parameters and associated detection limits for the Phase I studies is presented in Table 3.1-1.

For inorganic elements such as the metals the selection of an indicator range is more difficult. Indicator range were selected for the metals upon consideration of concentration ranges obtained from the literature search (Section 4.1), analysis of the bulk soil (Section 4.2), and the evaluation of data from uncontaminated areas of RMA (Section 4.3).

Recommended indicator levels are tabulated below:

<u>Element</u>	<u>Indicator Level $\mu\text{g/g}$ or ppm</u>
As	4.7-10
Cd	1-2
Cr	25-40
Cu	20-35
Hg	0.05-0.1
Pb	25-40
Zn	60-80

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Detectable levels of arsenic were encountered in 80 of the 798 uncontaminated area samples from the sections tabulated. Of these 80, a disproportionately large number (24) were in Section 36. Over 90 percent of the detected As values were under 10 ppm. Literature indicated As concentrations in western soils average 5.5 ppm. Arsenic was generally below detection in the bulk soil. An indicator range of 4.7 to 10 ppm was established for use in considering Phase II investigations.

Cadmium was detected in only 12 of the 798 uncontaminated area samples. The literature did not provide information on concentrations in western United States soils. Cadmium was generally below detection in the bulk soil. An indicator range of 1 to 2 ppm was established for use in considering Phase II investigations.

Detectable levels of chromium were encountered in 580 of the 798 uncontaminated area samples. Levels detected ranged from 7 to 55 ppm with the distribution skewed slightly to the lower end of the range. Literature values indicate Cr concentrations in western United States soils average 41 ppm. Chromium averaged 14 ppm in the bulk soil. An indicator range of 25 to 40 ppm was established for use in considering Phase II investigations.

Measureable concentrations of copper were encountered in 620 of the 798 uncontaminated area samples. Concentrations ranged from 5 to 53 ppm with the distribution skewed toward the lower end of the range. Approximately 60 percent of the detectable values were under 10 ppm. Literature values indicate Cu concentrations in western United States soils average 21 ppm. Copper averaged 10 ppm in the bulk soil. An indicator range of 20 to 35 ppm was established for use in considering Phase II investigations.

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Mercury was detected in 27 of the 798 uncontaminated area samples. Of these, a disproportionately large number (18) were in Section 36. Over 60 percent of the detected Hg values were under 0.1 ppm. Literature values indicate Hg concentrations in western United States soils average 0.46 ppm. Mercury was generally below detection in the bulk soil. An indicator range of 0.05 to 0.1 ppm was established for use in considering Phase II investigations.

Detectable levels of lead were encountered in 190 of the 798 uncontaminated area samples. Concentrations ranged from 11 to 120 ppm with the distribution skewed such that the median of detected Pb values was 20 ppm. Literature values indicate Pb concentrations in western United States soils average 5.5 ppm. Lead was generally below detection in the bulk soil. An indicator range of 25 to 40 ppm was established for use in considering Phase II investigations.

Zinc was detected in 682 of the 798 uncontaminated area samples. Concentrations encountered ranged from 12 to 280 ppm with the distribution skewed such that the median detected zinc value was 41 ppm. Literature values indicate Zn concentrations in western United States soils average 55 ppm. Zinc averaged 40 ppm in the bulk soil. An indicator range of 60 to 80 ppm was established for use in considering Phase II investigations.

Many of these values fall well within the ranges of natural variability found by the literature review. These levels must be considered as recommended concentrations above which further investigation may be performed but not necessarily levels at which a Remedial Action program is mandatory. Comparison of these values with action levels selected by the U.S. EPA and various states at NPL sites and with recommended concentrations for land treatment of hazardous waste indicates these levels are very conservative.

5.0 CHEMICAL IDENTIFICATION

5.1 IDENTIFICATION METHODS

In the desire to develop a complete and comprehensive analytical program to support the RI at RMA, the Army has developed a procedure to consider all the chemicals known to be associated with RMA for inclusion in Phase II studies. This approach involves three methods by which an analyte can be included in the second phase of the Remedial Investigation.

The first is the review of all available literature of past activities conducted by the Army and all tenants during the entire history of RMA. Because it is impossible to analyze for all chemicals associated with RMA, the Army screened the list and developed methods to quantify 48 separate analytes. These chemicals were chosen because of their known contribution to environmental contamination, their abundant use at RMA, and because of their significance in terms of public concern. Many of these chemicals are representative of classes of compounds used or manufactured at RMA. This list of chemicals served as the core group to be examined because of the likelihood of inclusion in the second phase of detailed investigation.

However, because of the possibility of missing a significant chemical or degradation product, the Army established a second screening method that required the data generated by GC/MS analyses be examined to identify the non-target compounds present. Any compound with a response greater than 10 percent of the internal standard response was possibly subject to the identification process. Because this requirement was very conservative and could potentially result in a large number of attempted identifications, a second restriction was initially used. Only the five non-target compounds exhibiting the highest response were examined in detail to attempt an identification. It was believed that with the number of samples being analyzed, the significant unknowns would occur at high enough concentrations and frequency to be included at one site or another.

This procedure was reviewed by other concerned parties and a recommendation was made to look at the top ten spectrum rather than the five proposed. The Army considered this a reasonable but arbitrary request and therefore went a step further and stated that they would eventually look at all non-target compounds to make sure that nothing was missed.

The third way in which a chemical may be included in Phase II is by recommendation from any involved party to this investigation. The Army will review all recommendations received and either include the analyte in Phase II or provide a justification for not including the compound.

5.2 NON-TARGET COMPOUND IDENTIFICATION

The overall procedures used for identification of non-target compounds involves the review of all peaks meeting the response criteria. Available GC/MS libraries are searched to develop the best three computer aided identifications. Once this is completed a GC/MS expert reviews all data to determine which, in any, of these three matches best fit the data. In some cases, none of the computer matches adequately represent the data and the operator attempts an identification based on his or her analytical chemistry experience and training.

Wherever possible the spectroscopist will make the "Best Fit" identification. While examining the mass spectra, the analyst will also make note of any unusual patterns that might indicate the presence of oil, other petroleum products, or chemicals common to similar hazardous waste areas.

These non-target compounds were labeled using the relative retention times as referenced to the internal standard. Non-target compounds found in the volatile analyses were labeled by multiplying the relative retention time by 100. For example, a volatile with a relative retention time of 1.33 would be labeled as "UNK133". Semi-volatile compounds were labeled using the same convention except 500 was added to the label (i.e., a semi-volatile retention time of 1.05 would result in a label of "UNK605").

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The results of these identification procedures are summarized in the table within each source report labeled "Tentative Identification of Non-Target Compounds in Source XX-YY". This information was developed for each borehole. Other information contained in these tables is provided to allow fast access to data for any future review.

In order to assess whether a non-target compound is significant enough for inclusion in the Phase II program, general screening criteria were established. Non-target compounds found that are known to be highly toxic will be added to the Phase II program. Others that are naturally occurring and appear at a reasonably ubiquitous concentration will not be included. Also chemicals that are identified as laboratory impurities will be excluded when found at similar concentrations at similar concentrations in the blank. Compounds with a questionable identification will also be excluded. All other identified compounds will be dealt with on a case by case basis to decide their significance.

It should be noted that during the start of the GC/MS analyses, a batch of methylene chloride that was used as an extraction solvent for semi-volatile compounds was found to contain trichloroethylene (TCE) as an impurity. This was verified in the solvent blanks in all four laboratories performing the analyses as well as other major laboratories throughout the country. Because of this, many of the early GC/MS runs contained hits for TCE that were identified as a "laboratory solvent impurity". This assessment was further verified by the fact that no TCE was found in volatile GC/MS analyses. A new batch of solvent was obtained and a significant decrease in the number of laboratory solvent impurities is anticipated.

5.3 PHASE II EFFORTS

With the implementation of these three screening techniques, the Phase II investigation program will include the chemicals that will drive any required engineering work. In this way, the best possible use of available time and resources will be made to define the extent of the problems at RMA and satisfy all parties that a thorough attempt at defining the sources of contaminants was made.

6.0 SOIL/GROUND WATER INTERACTIONS

6.1 HISTORICAL GROUND WATER DATA

Numerous comments on early drafts of the source reports revolved around the question of interaction between unsaturated zone contamination and ground water contamination, and the role of Phase I soils investigations in addressing this issue. The source reports include what were judged to be pertinent items from the large ground water data base. We have presented this information for the sake of completeness, recognizing that in at least some cases a relationship exists between the saturated and unsaturated zones. No attempt was made to positively establish the existence or lack of such relationships. Available data were not sufficient for this purpose.

As new ground water data becomes available from other tasks in this program, this discussion will be updated. An attempt will be made to use the historical data as a starting point for this analysis where it can be verified by more current studies.

6.2 PHASE II EFFORTS

In certain areas where the ground water table intersects the surface in a known highly contaminated area or data indicate such direct contact exists, Phase II sampling may continue below the water table. This will be done in areas such as Basin A (Source 36-1) where high ground water limits investigation of the vertical extent of contamination which is very evident in surficial soils. These situations will be evaluated individually and appropriate responses developed.

Where necessary, soils investigation tasks include the provision for installing wells to supplement the area wide ground water monitoring network. Data from the first quarter of ground water sampling completed under this program are currently under evaluation. The distribution of sampling points and the requirements for additional wells will be re-evaluated when this process is completed.